Solar System Exploration Division, GSFC Code 690

Venus gravity field modeling using Magellan and Venus Express data

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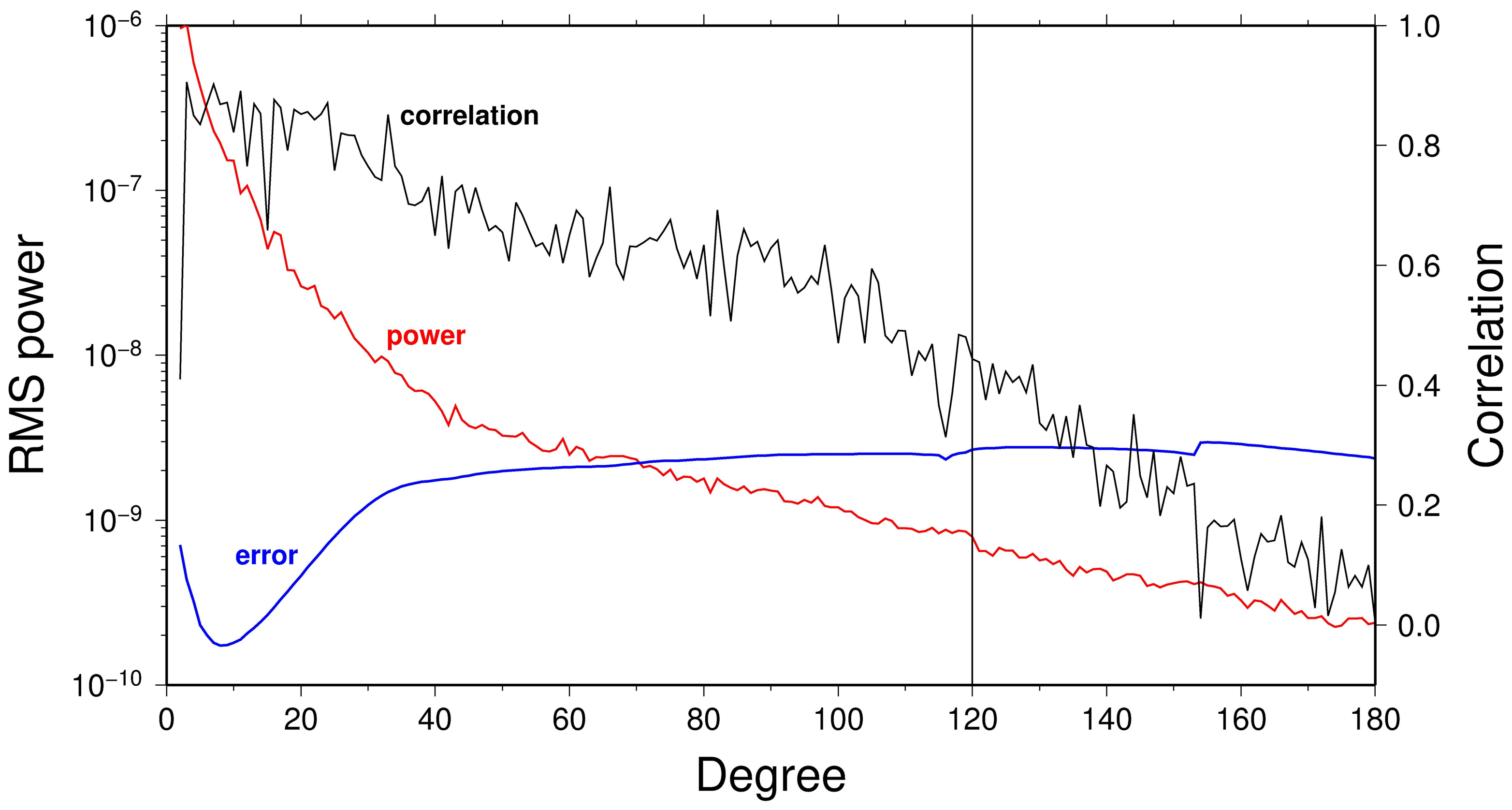
Introduction

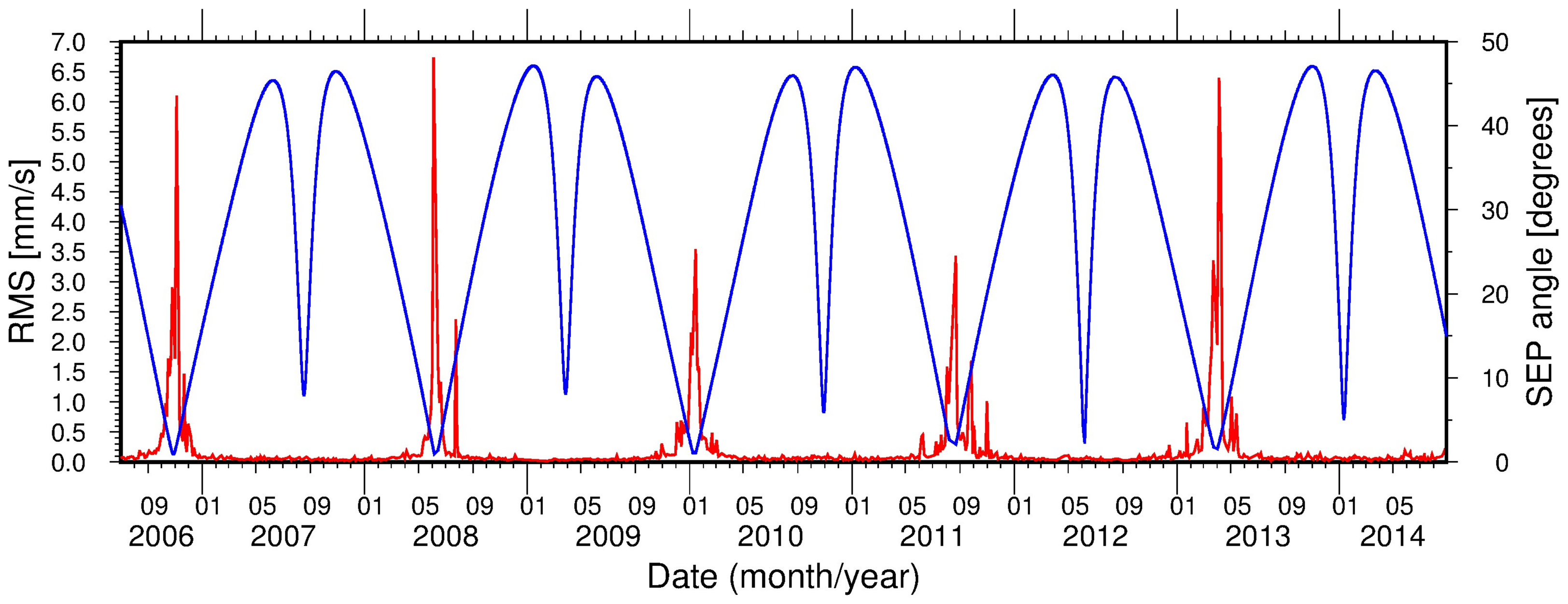
Joint analysis of gravity and topography can provide a powerful method to probe the interior structure of a planet, because the gravitational field of a planet depends on its internal density distribution. Models of planetary gravity fields are determined from satellite tracking data. For Venus, data from the Pioneer Venus Orbiter (1978-1980) and Magellan (1990-1994) spacecraft have been used, and the most recent gravity field model is an expansion in spherical harmonics of degree and order 180, called MGNP180U (Konopliv et al., *Icarus* **139**, pp.3-18, 1999). Due to computational constraints at the time, the potential coefficients of this model were estimated in successive batches, resulting in artificial discontinuities in the solutions and their error estimates (see below). This hampers the application in geophysical analysis of the models over their whole range, but especially at higher resolutions. Here, we present results of a reanalysis of the Magellan tracking data. We augment this data set with tracking data from the European Space Agency's Venus Express mission (VEX, 2006-2014).



Power and error spectrum for the MGNP180U gravity field model, as well as correlations with topography. **The breaks around degrees 120 and 155 are clearly visible**, resulting in staged spectra**. All our solutions consist of one-step inversions.**

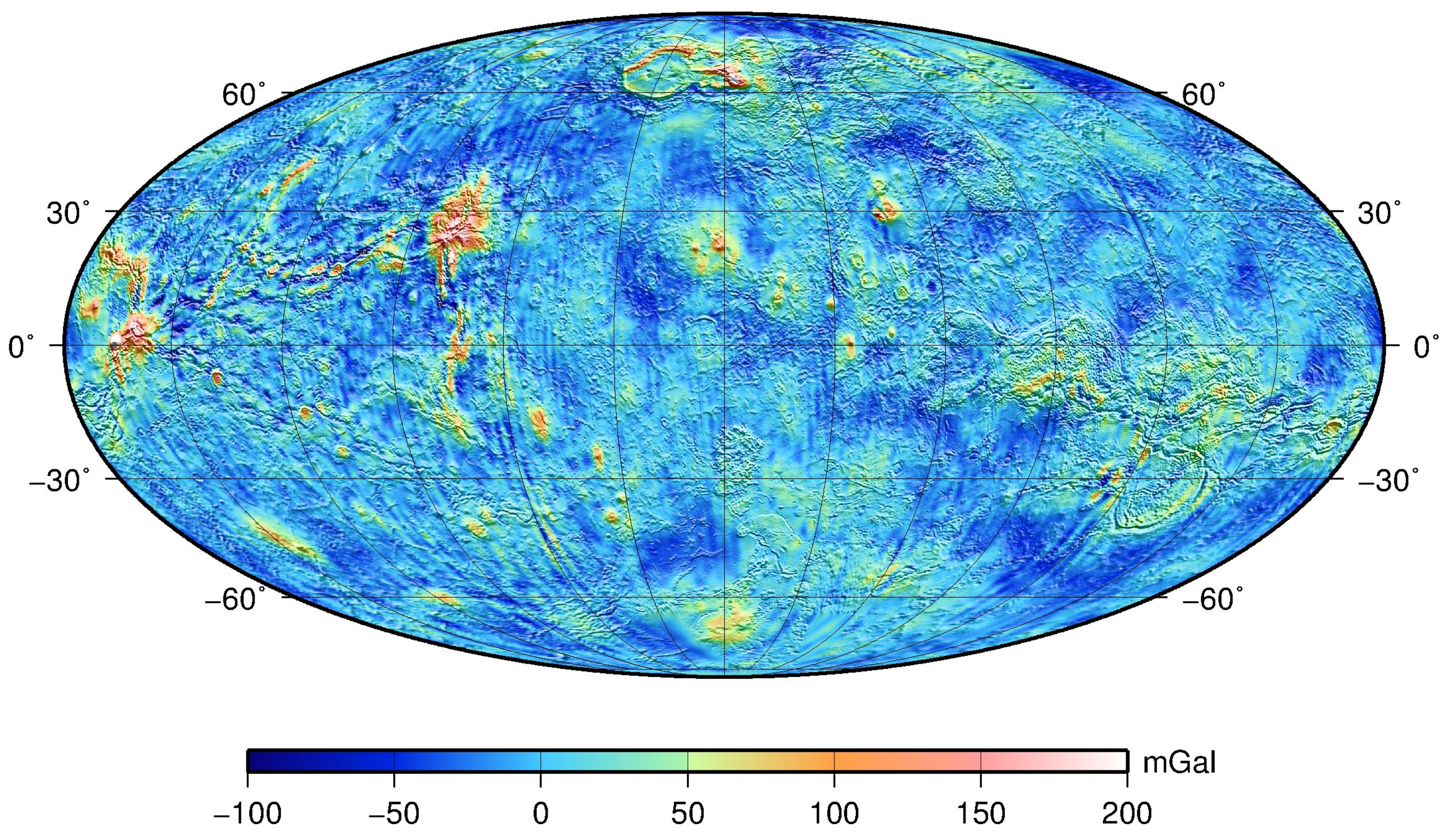
Processing strategy

We have analyzed tracking data from cycles 4,5 and 6 of Magellan (September 1992 – October 1994), and tracking data from Venus Express (covering the period 2006-2014). Tracking data are processed in continuous spans of time called arcs, by numerically integrating the equations of motion for the satellite state, **using our state-of-the-art processing software GEODYN II**. Our arc lengths are in general several days long, increasing sensitivity to long-wavelength features (lower degrees, Love number k_2). We use precise models for the forces acting on the satellite, and for the modeling of the measurements. We then compare the computed measurements with the tracking data, and their differences are used to adjust parameters of interest using batch least-squares. For our initial trial solutions, **we estimate a gravity field in spherical harmonics up to degree and order 200, and we include parameters such as *GM*, k_2 and Venus' rotational state**. We have used **Huber weighting** (measurements are down-weighted if they are above a given threshold) and **Variance Component Estimation (VCE)** in our solutions,. The latter results in a calibrated solution.

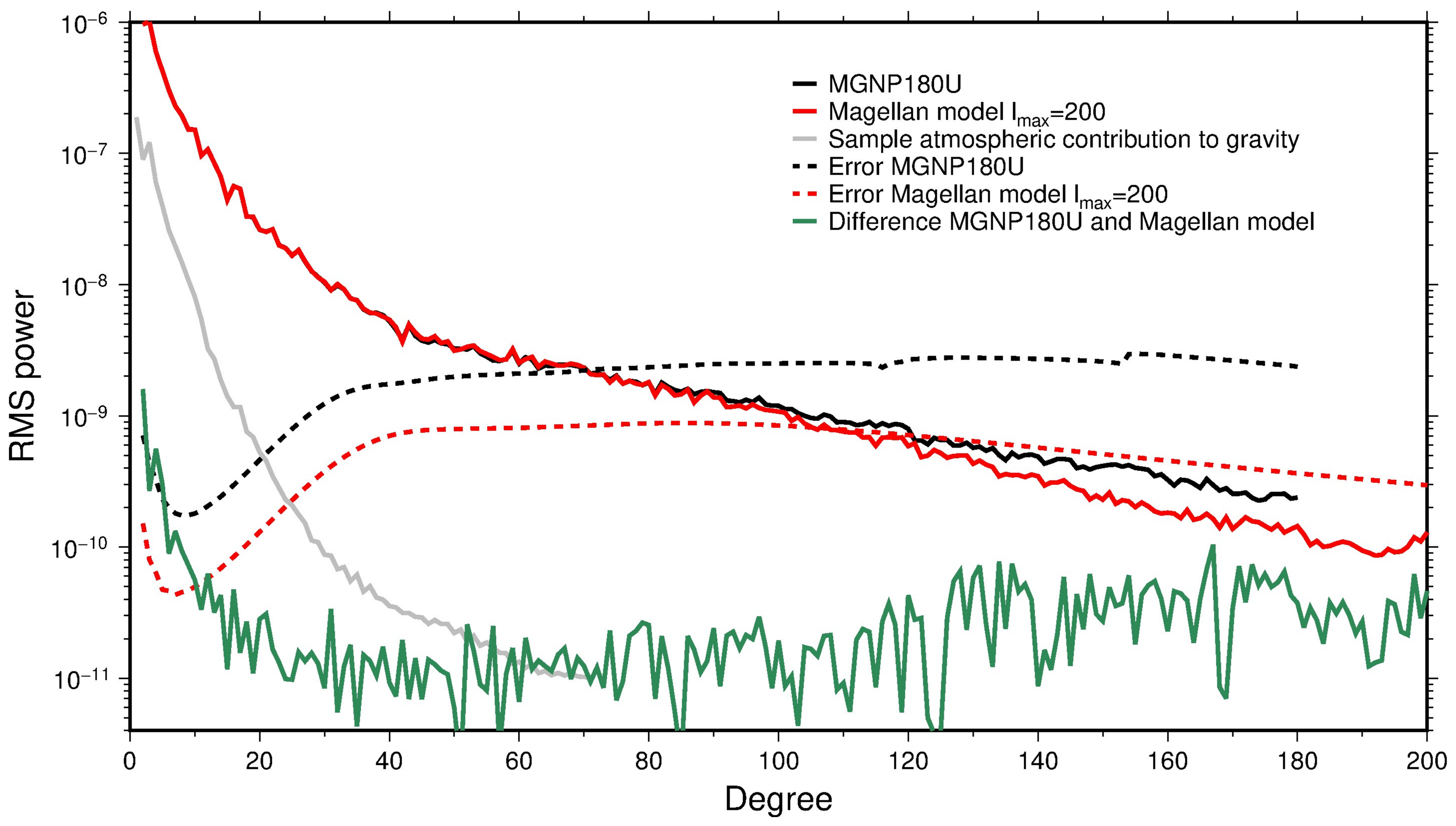


RMS of VEX X-band Doppler data fit, including the Sun-Earth-Probe (SEP) angle. For small SEP angles during superior conjunction, the tracking signal is affected by solar plasma, as indicated in the figure by the higher RMS values. We exclude these data from our solutions.

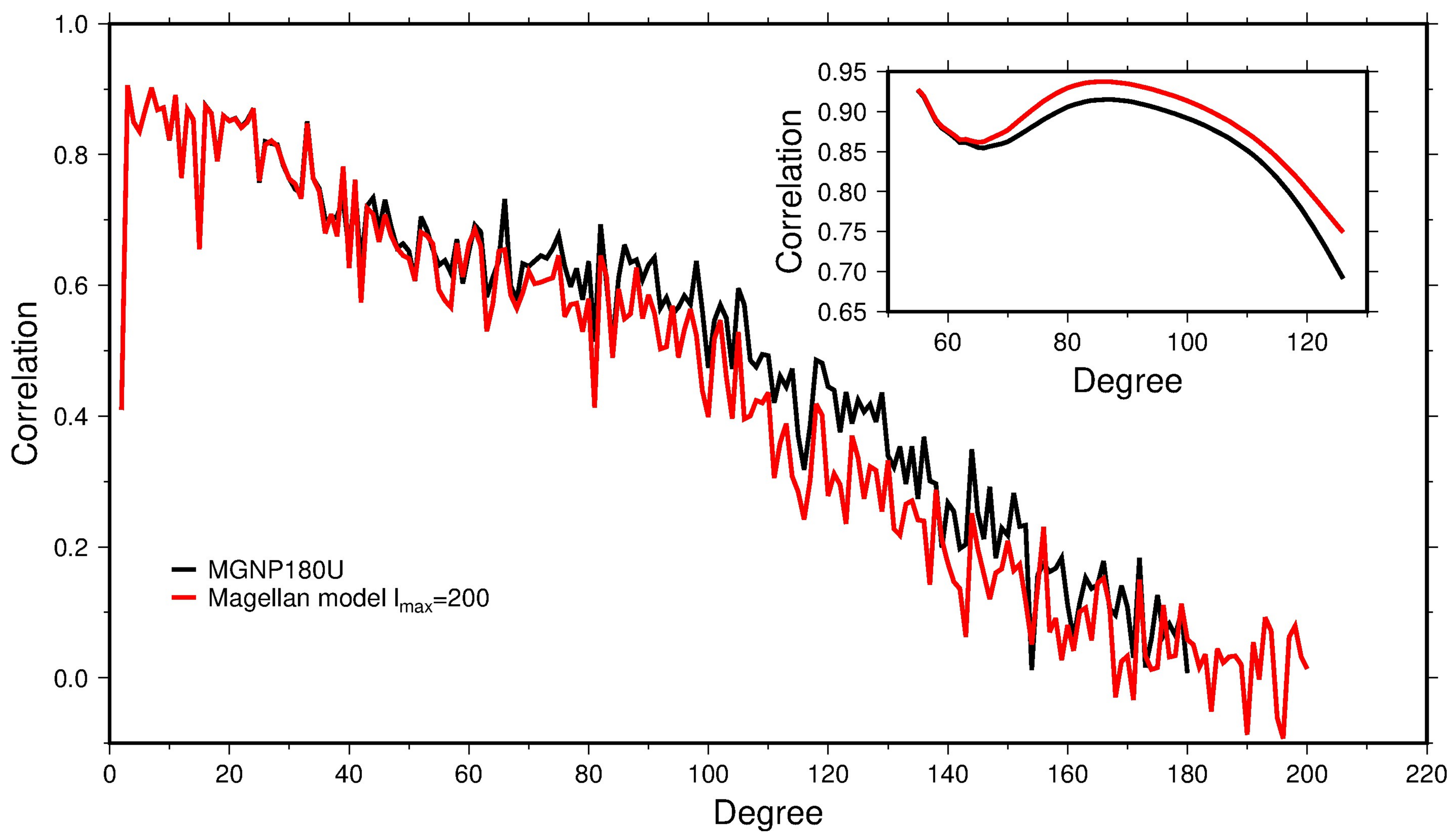
Results



Free-air gravity anomalies for our **trial solution using only Magellan data,** for spherical harmonic degrees 2 tot 200, shaded with radar topography. The map is in Mollweide projection centered on the prime meridian. This solution compares well to the existing MGNP180U solution (see below). **Our value for k_2 is 0.292 ± 0.008**, close to an earlier result (Konopliv and Yoder, GRL, 1996).



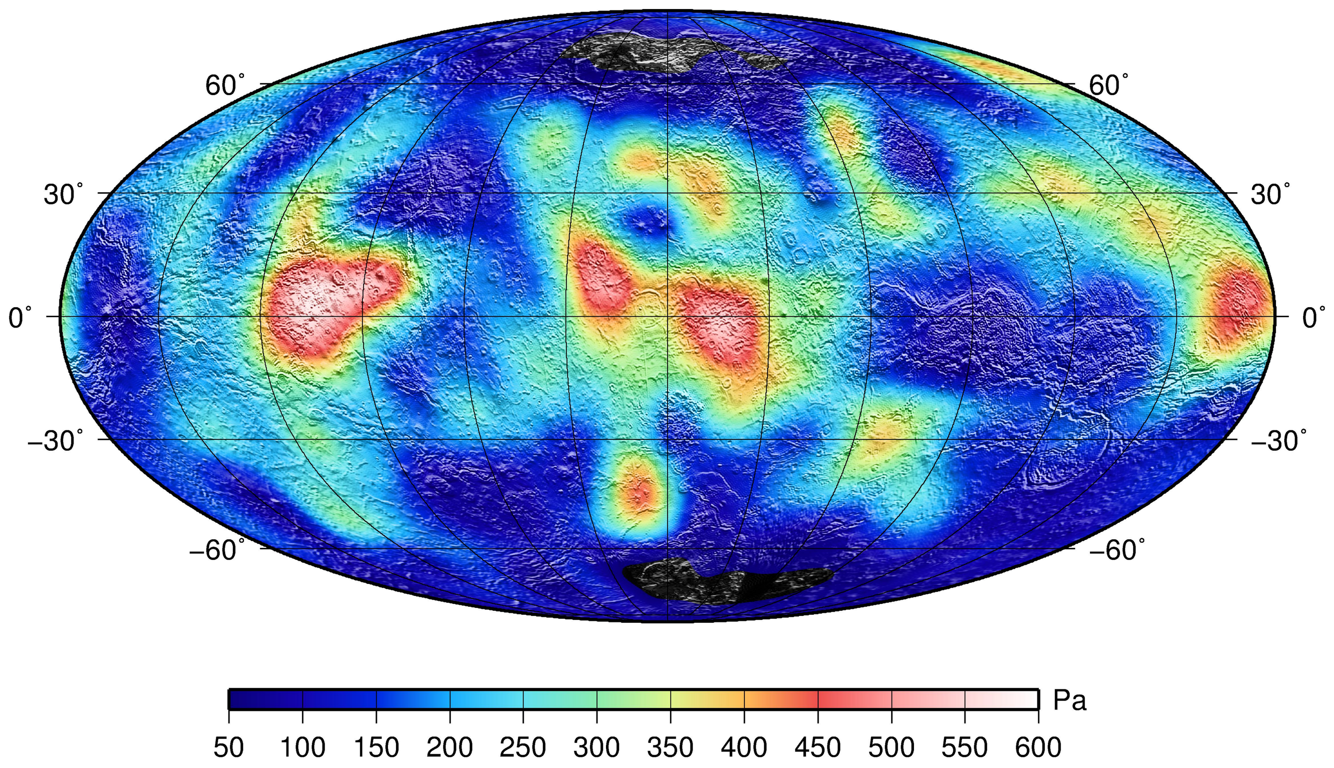
Power spectra of the existing MGNP180U solution and our new trial solution. We apply a Kaula rule ($1.2 \times 10^{-5}/l^2$) to our solution, whereas MGNP180U used a spatially varying constraint. The trial solution's power is suppressed after degree 80, likely due to the global Kaula constraint. Our inversion is a one-step inversion that results in a smooth power and associated error spectrum. **We calibrated our solution using VCE.** We also show the power spectrum of the effects of the atmosphere (see right column of poster). This indicates that the **atmospheric effects can be much larger than the errors on the coefficients at low degrees**, and can thus influence the gravity field results.



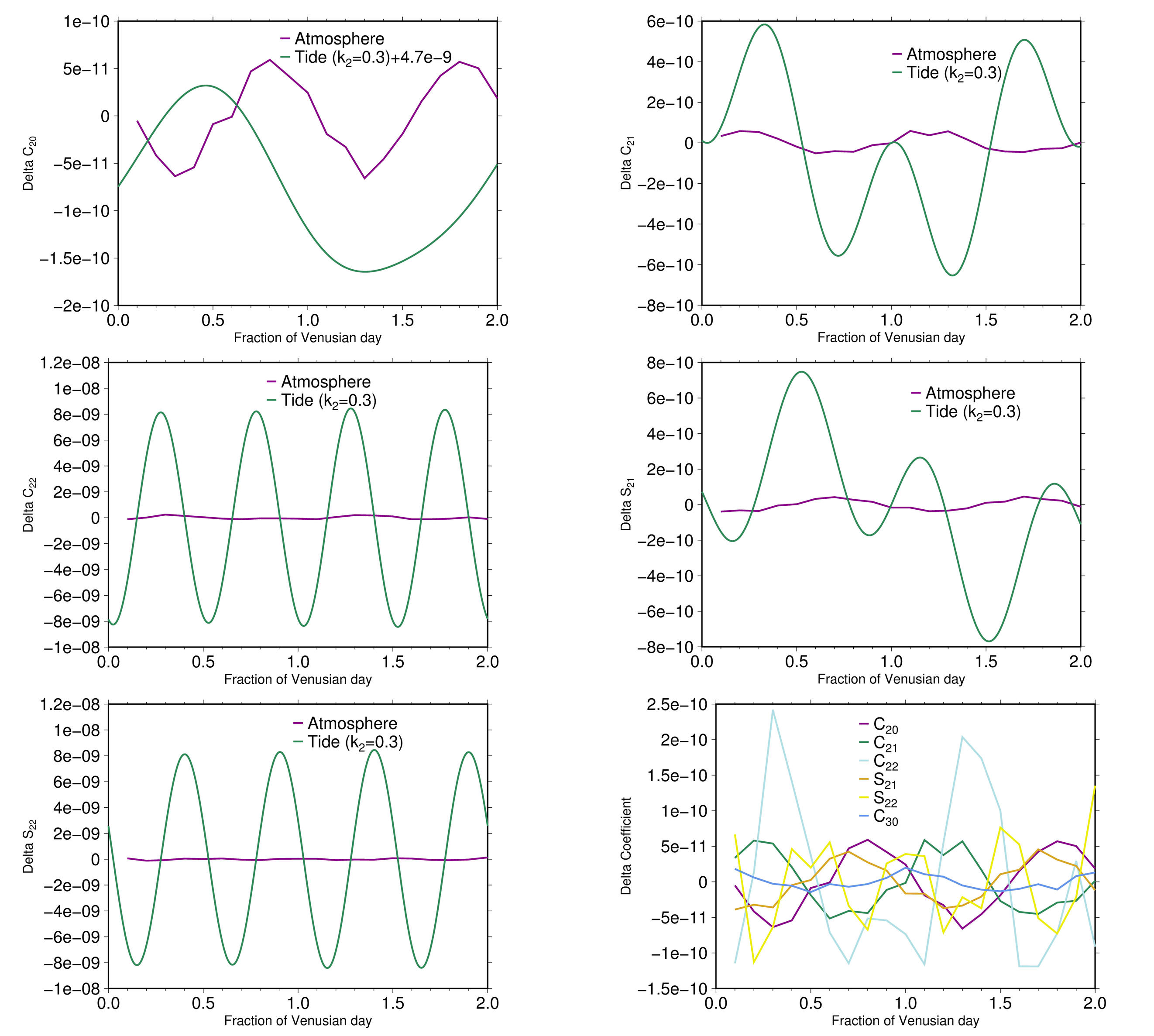
Correlations with topography, global and local (inset, localized over 10˚N, 175˚W, with a cap of 7.5˚). While global correlations drop after degree l=60, likely because our solution does not include Pioneer Venus Orbiter data, locally correlations have improved.

Atmospheric effects on the gravity field

The dense atmosphere of Venus affects the gravity recovery in several ways: through drag acting on the satellite, and through (time-varying) atmospheric effects on the gravity field itself. The latter has been modeled successfully for the Earth and Mars. We use a model for the density of Venus' atmosphere, and estimate scale factors on the force exerted on the spacecraft by atmospheric drag. In addition **we will model the atmospheric gravity variations by converting pressure fields derived from Venus Global Circulation Models into a time series of gravity coefficients** expressed in spherical harmonics (Petrov and Boy (2004), *J. Geophys. Res.* (**109**), B03405).



RMS of pressure variations around the mean over two Venusian days, using a model with initial conditions close to observations of superrotation. Each pressure field is converted into gravity spherical harmonics (of maximum degree and order 71) to account for changes in the planet's gravitational field.



Atmospheric effects on degree 2 gravity coefficients, shown as variations around the mean. Due to high pressures, mean values are large. Together with **sizeable variations** (compared to the influence of solid tides), this **will affect the gravity recovery**.

Summary and Outlook

We have processed the Magellan and VEX data and made our first trial runs with 200x200 solutions based on Magellan data. We will augment our solutions with VEX data in order to increase the time-span for our data analysis, with the goal to estimate the full gravity field and associated parameters such as k_2 Love numbers. Our inclusion of atmospheric effects in our future analysis means one can decouple the solid tides from atmospheric tides, and directly estimate the solid tidal Love number, which will better constrain models of the interior structure.

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